Summary of Safety and Effectiveness Data

P910023/S47
Panel Track PMA

St. Jude Medical, Inc.

Photon™ DR Model V-230HV
Dual Chamber Implantable Cardioverter Defibrillator
with Model 3307 Programmer Software

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SUMMARY OF SAFETY AND EFFECTIVENESS

I. GENERAL INFORMATION

Device Generic Name:	Dual Chamber Implantable Cardioverter Defibrillator (ICD) System
Device Trade Name:	Photon™ DR Model V-230HV Implantable Cardioverter Defibrillator System with Model 3307 Programmer Software, v1.3
Applicant's Name and Address:	St. Jude Medical Cardiac Rhythm Management Division 15900 Valley View Court Sylmar, CA 991342 (408) 738-4883
PMA Number:	P910023/Supplement 47
Date of Panel Recommendation:	No Panel Meeting
Date of Notice of Approval to Applicant:	October 27, 2000

II. INDICATIONS FOR USE

The St. Jude Photon DR pulse generator is indicated for use in patients with a history of hemodynamically compromising ventricular tachyarrhythmias. These patients may have experienced a cardiac arrest not associated with acute myocardial infarction or have ventricular tachyarrhythmias. In addition, the pulse generator can be used in patients whose primary therapy for hemodynamically significant, sustained ventricular tachycardia is antitachycardia pacing; the defibrillation capabilities of the device provide high-energy therapy in the event that the arrhythmia accelerates. The pulse generator can be implanted in either the pectoral region or the abdominal region, at the physician's discretion

III. CONTRAINDICATIONS

Contraindications for use of the Photon DR pulse generator system include ventricular tachyarrhythmias resulting from transient or correctable factors such as drug toxicity, electrolyte imbalance, or acute myocardial infarction. The Photon DR pulse generator provides dual-chamber bradycardia pacing. If another pacemaker is used, it should have a bipolar pacing reset mode and be programmed for bipolar pacing to minimize the possibility of the output pulses being detected by the device.

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IV. WARNINGS AND PRECAUTIONS

See the labeling.

V. DEVICE DESCRIPTION

The St. Jude Medical Photon DR pulse generator is an implantable cardioverter/defibrillator (ICD) that monitors and regulates a patient's heart rate by providing ventricular tachyarrhythmia therapy and single- or dual-chamber bradycardia pacing with rate adaptive response (DDD(R)). The pulse generator, along with the compatible, commercially available sense/pace leads and transvenous cardioversion/defibrillation leads, constitutes the implantable portion of the ICD system. The St. Jude Medical Model 3510 Programmer, the version 3307 software, and a telemetry wand constitute the external portion of the ICD system.

Photon DR Pulse Generator

The Photon DR can detect up to three different ventricular tachyarrhythmias based on rate criteria and, in response, deliver antitachycardia pacing, cardioversion or defibrillation therapy. Tachycardia and fibrillation shock therapy can deliver either a biphasic or monophasic truncated exponential waveform. The shock waveform has a maximum stored energy of 37 joules and can be programmed to be delivered as either Fixed Tilt (42, 50, 60 or 65%) or Fixed Pulse Width. It is designed with non-invasive programmable stimulation and fibrillation induction features (including direct current DC Fibber, Burst and shock-on-T) for the induction of tachyarrhythmias and evaluation of therapy. Defibrillation threshold testing can be performed using Manual, Timed or Automatic methods. The DDD(R) bradycardia pacing features include an accelerometer sensor, Auto PMT (pacemaker mediated tachycardia) Detection and Termination, Auto Rate Response, Auto Rest Rate, Auto Mode Switch and DDD Hysteresis with Search.

To differentiate between ventricular and supraventricular tachyarrhythmias, a feature that is unique to the Photon DR ICD is its dual chamber (atrial-ventricular) A-V Rate Branch discrimination algorithm, which incorporates Morphology Discrimination, Interval Stability (with AV Association) and Sudden Onset. The Morphology Discrimination feature also includes Automatic Template Maintenance, which updates the morphology template based on dynamic changes in the patient's baseline intracardiac electrogram signals.

The pulse generator stores detailed information on up to 60 events, including dates and times, initial SVT/VT discrimination results, therapies delivered, therapy results, etc. Approximately twenty-five minutes of fully annotated electrograms (EGMs) from one channel or twelve minutes from two channels with the waveform source programmable to either bipolar (atrial and/or ventricular) or custom can be stored. The type of events to be stored, the criterion

for storage, the maximum duration, and the EGM source are all programmable.

Real-time information is also available, including R- and P-wave amplitude, fully annotated EGMs, morphology scoring, battery voltage, residual high-voltage capacitor voltage, pacing lead impedance, and high-voltage lead impedance. The device also automatically stores battery voltage, pacing lead impedance and signal amplitude measurements once a month, which are kept for the life of the device.

Model 3307 Programmer Software

Programming information is sent to the implanted pulse generator through the telemetry wand using the Model 3307 Programmer Software, v1.3. The software runs on the commercially available St. Jude Medical Model 3510 Programmer. In addition, the programmer has an internal printer that can be used to print surface electrocardiograms (ECGs); captured, stored, or real-time EGMs; screens; or reports.

VI. ALTERNATE PRACTICES AND PROCEDURES

Cardioversion and defibrillation is an accepted treatment for the indications described in the Indications For Use section above. The alternatives to the Photon DR system are antiarrhythmic drug therapy, antiarrhythmia therapy surgery, and/or other legally marketed implantable cardioverter/defibrillators.

VII. MARKETING HISTORY

The Photon DR System is currently legally marketed in the following countries: Austria, Spain, Portugal, Germany, Italy, Sweden, Switzerland, England, Northern Ireland and Greece. The system has not been removed from any of these countries for any reasons related to the safety and effectiveness of the device.

VIII. ADVERSE EVENTS

Reported Adverse Events

The Photon DR implantable cardioverter/ defibrillator (ICD) clinical trial involved 106 patients with implanted systems and 16,198 cumulative implant days (44. 4 years). The mean implant duration was 151 days (ranging from <1 day to 211 days). One additional patient had an attempted Photon DR implant; however, the device was not implanted because of high defibrillation thresholds and the patient received a higher output legally marketed Contour MD pulse generator.

Table 1 lists the observations and complications reported from this clinical trial (see Section X below). In this study, a clinical complication is defined as a clinical event with potential adverse effects that requires invasive intervention to treat or resolve. A clinical observation is clinical event with potential adverse

effects that do not require invasive intervention. A total of 8 complications and 33 observations were reported in 28 patients during the Photon DR clinical investigation. The three-month complication-free survival for the Photon DR population was 94.2%.

Table 1: Adverse Events

	# Pts with AEs (n = 107)	% of Pts with AEs	# of AEs	AE/pt-years (n = 44.4 yrs)
Complications (total)	**7**	**6.5%**	**8**	0.18
Lead dislodgment	2	1.9%	2	0.045
Infection	2	1.9%	2	0.045
Bleeding/hematoma	1	0.9%	1	0.023
Pneumothorax	1	0.9%	1	0.023
Surgical removal of Jelco catheter	1	0.9%	1	0.023
Suspected generator malfunction	1	0.9%	1	0.023
Observations (total)	**24**	**22.4%**	**33**	**0.74**
Inappropriate device mode switching due to Far-R sensing	9	8.4%	15	0.338
Inappropriate therapy delivery due to misdiagnosis of SVT as VT [1]	4	3.7%	5	0.113
Elevated ventricular pacing threshold	3	2.8%	3	0.068
Bleeding/hematoma	2	1.9%	2	0.045
Elevated defibrillation threshold (DFT)	2	1.9%	2	0.045
Sensing of external stimuli/noise resulting in aborted therapy	2	1.9%	2	0.045
Device reset during inductions	2	1.9%	2	0.045
Pericardial effusion	1	0.9%	1	0.023
Hex wrench broke off in device header	1	0.9%	1	0.023

[1] *These observations include inappropriate therapies delivered when the device was programmed to "monitor"*

Potential Adverse Events

Possible adverse effects (in alphabetical order) associated with ICD systems, such as the Photon DR, include, but are not limited to the following:

- Acceleration of arrhythmias (caused by device)
- Air embolism
- Bleeding
- Chronic nerve damage
- Erosion
- Excessive fibrotic tissue growth
- Extrusion
- Fluid accumulation
- Formation of hematomas or cysts
- Inappropriate shocks
- Infection
- Keloid formation
- Lead abrasion and discontinuity

- Lead migration/ dislodgment
- Myocardial damage
- Pneumothorax
- Shunting current or insulating myocardium during defibrillation with internal or external paddles
- Potential mortality due to inability to defibrillate or pace
- Thromboemboli
- Venous occlusion
- Venous or cardiac perforation.

Patients susceptible to frequent shocks despite antiarrhythmic medical management may develop psychological intolerance to an ICD system that may include the following:

- Dependency
- Depression
- Fear of premature battery depletion
- Fear of shocking while conscious
- Fear that shocking capability may be lost
- Imagined shocking (phantom shock).

IX. SUMMARY OF PRECLINICAL STUDIES

Photon DR Verification and Validation Tests

The legally marketed single chamber Profile MD pulse generator was modified in order to create the Photon DR device. Additionally, the features of the legally marketed Affinity DR pacemaker were added in order to support dual chamber bradycardia pacing.

Each major new component and process underwent specific investigation. The pulse generator's software system was verified using a formal software path analysis to demonstrate proper software path execution. Testing of programmer software Model 3307 was performed through manual and automated tests. Analysis of code coverage during the testing and code reviews showed that one hundred percent of the code had been covered. In addition, extensive system functional testing and user testing were performed to validate proper performance of the pulse generator/programmer system. The laboratory testing that was completed for the Photon DR device is summarized below in Table 2. All tests were completed successfully and the pulse generator met all required specifications for human clinical use in accordance with established National and International industry standards, or St.Jude's specifications.

Table 2: Summary of Preclinical Laboratory Testing

Test Performed	Sample Size	Test Results
Component Testing		
Hybrid Verification: life tests, temperature characterization, temperature cycling, constant acceleration, wire bond pull, die shear test, and stabilization bake	6-22	PASS
Header System Verification: dimensional, visual, contact resistance, push test, torque test, 10-day soak, isolation impedance, insulation resistance, insertion/withdrawal, current carrying, temperature cycle, HV (high voltage) electrical isolation	24	PASS
High Voltage Capacitor Component Verification	10	PASS
Controller IC (integrated chip)Verification: temperature cycling, temperature characterization, acceleration tests, SEM (scanning electron microscope) analysis, wire bond pull and life tests	6-22	PASS
I/O (input/output) Chip Verification: temperature cycling, temperature characterization, acceleration tests, SEM analysis, wire bond pull and life tests	6-22	PASS
High Voltage Controller IC Verification: temperature cycling, temperature characterization, acceleration tests, SEM analysis, wire bond pull and life tests	6-22	PASS
Gate Drive IC Verification: temperature cycling, temperature characterization, acceleration tests, SEM (scanning electron microscope) analysis, wire bond pull and life tests	6-22	PASS
EMI (electromagnetic interference) Coil Verification	33	PASS
High Voltage Transformer Verification	33	PASS
Filtered Feedthru Verification	22	PASS
Telemetry Coil Qualification	22	PASS
Finished Device Testing		
Electrical Verification: HV shock, magnet test, telemetry mapping, burst fibber, pacing duration, pulse interval, pulse rate, pulse amplitude, A-V interval, sensing threshold, escape interval, sensing and pacing refractory periods, pacing lead and input impedances	6	PASS
Mechanical Verification: functional testing, visual/x-ray test, multiple sterilization, temperature storage,	12	PASS

irradiation, pressure, packaging, shipping, mechanical shock, squeeze test, and product/package markings		
External Defibrillation Validation	6	PASS
Electrosurgical Unit Susceptibility	6	PASS
Electromagnetic Interference Susceptibility	6	PASS
Cellular Phone Susceptibility	3	PASS
Process Testing		
Hermetic Welding of can	12	PASS
Welding L tab to case interior	60	PASS
Welding feedthru wire to connector block	60	PASS
Pre-tinned and gold removal process	12	PASS
Sterilization Cycle	5-30	PASS
Packaging	18	PASS
Software Testing		
Device software tests	Current version of device software	PASS
Programmer software tests	Current version of programmer software	PASS
System Testing		
Photon DR System Validation	3	PASS
Animal Testing		
Canine	4	PASS

Biocompatibility Testing

All materials used for the Photon DR pulse generator are currently used in legally marketed Ventritex/St. Jude Medical pulse generators and have been previously tested and approved for their biocompatibility.

Animal Testing

An animal study (canines, n = 4) was conducted to confirm the results of the bench testing and evaluate the operation and effectiveness of the Photon DR system under conditions simulating human use. The results of the animal study demonstrated that the new features incorporated in the Photon DR device functioned properly under clinical conditions.

X. SUMMARY OF CLINICAL STUDY

The St. Jude Medical, Inc. Photon DR clinical study was conducted under an IDE (investigational device exemption).

Primary Objective

The primary objective of the study was to determine whether the dual-chamber sensing/discrimination capabilities affect the ability of the defibrillator to detect and redetect ventricular fibrillation. The detection and redetection times were compared to a recent historical control group (Contour MD/Angstrom MD ICD clinical trial, PMA File Number P910023/S33) in order to demonstrate equivalent performance.

Additional Data

In addition to the primary objective, the following data was also summarized:

- Patient demographics
- Supraventricular arrhythmia discrimination performance of the device using the dual-chamber sensing/discrimination capabilities
- Complication and observation rates and complication-free survival at three months for the Photon DR system
- VT and VF diagnosis and therapy
- DC Fibber induction effectiveness
- Manual and Timed device based testing methods
- Automatic update of the morphology template

Subject Selection and Exclusion Criteria

One hundred eight (108) patients had been enrolled in the Photon DR clinical study. One hundred six (106) patients received a Photon DR device. Two additional patients were enrolled in the study but were not implanted with a Photon DR device. One of those patients was intended for Photon implant; however, the implant attempt was abandoned due to unacceptably high defibrillation thresholds (the patient received a higher output Contour MD device). This patient is represented in the demographic, primary endpoint, and observation/complication analyses but is not included in the other analyses based on not having received a Photon system. The second patient experienced a surgical complication related to the extraction of a chronic lead before the Photon DR device implant was attempted. This patient is therefore not represented in any of the analyses. Nineteen investigational sites (15 in the U.S. and 4 in Europe) participated in this study.

Study and Historical Populations

The patient demographics for the study population (Photon DR) and historical control population (MD group) are shown below in Table 3. A comparison of demographic information for the 107 patients in the Photon DR study population and the 161 patients in the MD control group indicated that there was not a

statistically significant difference for all demographic variables, except age. The Photon DR study group was on average slightly older than the MD group by 3.4 years.

Table 3: Patient Demographics

	Photon DR (n = 107)	Control (n = 161)
Sex - % Male	80.4%	83%
Age (mean)	66.4 years	63 years
Arrhythmia Diagnosis		
VF	14%	14%
VT	56%	54%
VT/VF	30%	32%
Structural Disease		
Coronary Disease	78.5%	80%
Cardiomyopathy	13.1%	11.8%
Ejection Fraction (mean)	33.5%	34%

Photon DR Lead Systems

A lead system consisting of an atrial pace/sense lead and a dual-coil single-pass defibrillation lead was implanted in 84.1% of patients. The leads used with the Photon DR pulse generator are shown below in Table 4.

Table 4: Lead Systems

Atrial Lead	**Number of Patients**
Pacesetter 1388	104
Pacesetter 1342	1
Pacesetter 1188	1
Pacesetter 1488	1
TOTAL	**107**
Ventricular Lead	**Number of Patients**
Ventritex SP01[2]	28
Ventritex SP02[2]	62
Ventritex RV02[3]	12
Ventritex 1559[3]	3
Ventritex RV02/ Ventritex SV02[4]	1
Medtronic 6943[3]	1
TOTAL	**107**

[2] Dual-coil single-pass defibrillation lead
[3] Single-coil RV defibrillation lead
[4] SVC defibrillation lead

Study Period

Patient enrollment duration is calculated as the number of days between the patient's initial implant date and either the date of the patient's termination from the study or the final date used for data collection. The cumulative number of patient enrollment days was 16,198 days (44.4 years). The minimum number of days for which a patient was enrolled in the study was less than 1, the maximum was 211, and the mean was 151 days (approximately 5 months).

Study Results

The primary endpoint of the study involved comparison of detection and redetection times of VF episodes between the Photon DR study population and the historical control. Detection and redetection times were calculated for all induced VF episodes for which a stored intracardiac electrogram was available. The results are shown below in Table 5. The mean, as well as the median, detection time and redetection times for Photon DR devices were less than the corresponding values for MD defibrillators. In addition, the distributions for both detection and redetection times for the Photon DR group were tighter (i.e., had smaller ranges and standard deviations) than the corresponding distributions for the MD group. The Photon DR group had statistically equivalent median detection and redetection times to the control group ($p < 0.0004$ for equivalence).

Table 5: Detection and Redetection Times

	Photon DR	**Control**
Detection Time		
No. of episodes	374	200
Mean ± s.d.	2.8 ± 0.5 sec	3.3 ± 1.0 sec
Median	2.8 sec	3.0 sec
Range	1.7 to 6.0 sec	1.8 to 12.0 sec
Redetection Time		
No. of episodes	128	200
Mean ± s.d.	1.3 ± 0.3 sec	1.8 ± 1.0 sec
Median	1.3 sec	1.4 sec
Range	0.2 to 2.4 sec	0.9 to 5.8 sec

Study inclusion and exclusion criteria were designed and the study was carried out to avoid any gender bias in patient enrollment. The lone exception to this was the exclusion of pregnant women. Approximately 20% of the patients included in the clinical investigation were female (see Table 3 above). This is representative of the general clinical population that receives ICD therapy and is comparable to past trials investigating ICD's. Table 6 below shows that the Primary Endpoint (detection and redetection times) results are not statistically significantly different based on gender.

Table 6: Gender Bias Analysis for Primary Endpoint

	Males (n = 86)	Females (n = 21)
Detection Time		
No. of episodes	283	91
Mean ± s.d.	2.8 ± 0.4 sec	2.9 ± 0.6 sec
Median	2.8 sec	2.8 sec
Range	1.7 to 4.8 sec	1.7 to 6.0 sec
Redetection Time		
No. of episodes	93	35
Mean + s.d.	1.3 ± 0.3 sec	1.3 ± 0.3 sec
Median	1.3 sec	1.3 sec
Range	0.8 to 2.4 sec	0.9 to 2.2 sec

Supraventricular Arrhythmia Discrimination Performance

The dual chamber discrimination algorithm's ability to differentiate between ventricular and supraventricular tachyarrhythmias was also assessed during the study. The data was analyzed for the parameters set to the nominal settings: 60% with 5 out of 8 matches for morphology discrimination, 80 ms for interval stability and 100 ms for sudden onset. Performance of the SVT discriminators did not affect the detection of any ventricular fibrillation episodes; the Photon device appropriately diagnosed one hundred percent (100%) of VF episodes. A total of 160 tachycardia episodes were evaluated where the clinical diagnosis, based on review of two-channel stored electrograms, was VT in 83 cases and SVT in 77 cases. Episodes included simultaneous AF with VT, as well as 1:1 retrograde VT. SVT/VT discriminator performance showed a sensitivity of 100% and a specificity of 84%.

Defibrillation Thresholds and Conversion Efficacy

The mean defibrillation energy requirements of this population (10.0 joules, 431 volts) were not statistically significantly different than in the historical control population (9.6 joules, 418 volts). The conversion efficacy of all sustained induced arrhythmias was 99.6%. All (100%) of the sustained spontaneous episodes were terminated by the implanted system. Thus, 99.7% of all sustained episodes experienced by the study population were terminated by the implanted Photon DR system.

DC Fibber Induction Method

The DC Fibber method was the induction method of choice for 81% of the ventricular arrhythmia inductions performed during the clinical investigation. The rate of successful first attempt induction using this method was 96.4%.

Manual and Timed Device-Based Testing Modes

Either the Manual or Timed therapy method was chosen as the first therapy method during device-based testing in 86% of the Photon DR implants. In every case, the programmed therapy was delivered appropriately, both when the

clinician initiated the Manual method or when the programmed time had elapsed while using the Timed method.

Automatic Morphology Template Update

The Automatic Morphology Template Update feature was programmed ON in 97% of the patients. Stored electrograms documented Automatic Morphology Template updates. The Automatic Morphology Template Update feature was observed to perform appropriately throughout the study.

Patient Discontinuation

Twelve patients participating in the Photon DR clinical investigation were withdrawn from the study. Eight of those patients were withdrawn from the study due to death. An independent Events Committee felt that none of the deaths were attributable to the Photon device and classified the deaths as shown below in Table 7. Three of the eight deaths (38%) were considered to be procedure related, and four of the eight (50%) were considered to be peri-operative mortalities (i. e., occurred $\leq$ 30 days post-implantation).

One patient had the Photon DR system removed for infection. Another patient had the Photon DR system explanted prior to receiving a heart transplant. In one patient, the implant attempt was abandoned due to unacceptably high defibrillation thresholds and the patient received a higher output Contour MD device. One additional patient had their device removed for suspected pulse generator failure. All of these four patients are known to be alive.

Table 7: Causes of Deaths

Cause of Death	No. of Patients
Cardiac-arrhythmic/sudden	0
Unknown/sudden	1
Cardiac-arrhythmic/non-sudden	3
Cardiac non-arrhythmic/non- sudden	3
Non-cardiac/non-sudden	1

Device Failures and Replacements

In one case, the patient's device was explanted due to a suspected malfunction. A second patient had their device explanted due to infection. In both cases, the devices were replaced with non- investigational devices.

XI. CONCLUSIONS DRAWN FROM THE STUDIES

All of the relevant non-clinical laboratory testing, including animal testing, was conducted prior to the clinical study of the Photon DR system. Further, the clinical study found that the Photon DR group had statistically equivalent median detection and redetection times to the control group. There were no unknown adverse events reported. Thus, the results of the bench tests, animal and clinical studies provide reasonable assurance of safety and effectiveness of the Photon DR

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system, including all of the associated components, when used as indicated in accordance with the directions for use.

XII. PANEL RECOMMENDATIONS

Pursuant to section 515(c)(2) of the Food, Drug and Cosmetic Act (the Act) as amended by the Safe Medical Devices Act of 1990, this PMA supplement will not be referred to Circulatory System Devices, an FDA advisory panel, for review and recommendation because the information in the PMA substantially duplicates information previously reviewed by this panel.

XIII. FDA DECISION

Based on the reviews of the PMA supplement (panel track) application and its amendments, FDA determined that the device provides reasonable assurance of safety and effectiveness when used as indicated in the labeling. FDA found St. Jude Medical, Inc.'s manufacturing facility to be in compliance with the Device Quality System Regulation (21 CFR part 820).

XIV. APPROVAL SPECIFICATIONS

Directions for use: See the labeling.

Hazards to Health from Use of the Device: See Indications, Contraindications, Warnings, Precautions and Adverse Events in the labeling.

Post-approval Requirements and Restrictions : See approval order.

The Approval Order, Summary of Safety and Effectiveness Data, and labeling can be found on the Internet at http: //www.fda.gov/cdrh/pmapage.html.